Enhanced Delta Smelt Monitoring
2021 Phase 2 Sampling
Preliminary Analysis

DRAFT

U.S. Fish and Wildlife Service

July 7, 2021

Overview

On March 29, 2021, the Enhanced Delta Smelt Monitoring (EDSM) program started its Phase 2 sampling program for postlarval and juvenile Delta Smelt. In order to improve our ability to make inferences about the population, sampling effort is being focused on six geographic areas where Delta Smelt are likely to be caught based on historical data. Sampling locations are generated using a generalized random-tessellation stratified (GRTS) design [Stevens and Olsen, 2004] with stratification and equal probability sampling. Trawling gear similar to that used in the California Department of Fish and Wildlife's 20 mm Survey is used to conduct two tows per site.

In some previous years, the trawl was towed obliquely with a single boat as in the 20 mm Survey. This year, the trawl will be towed at the surface with a single boat. This change is based on experimental larval sampling in spring 2018 and 2019, the results of which indicated we could improve our ability to detect these early life stages of Delta Smelt by using surface tows. This is potentially because densities near the surface are higher than densities at depth. In an attempt to standardize abundance estimates based on surface tows with estimates from previous years based on oblique tows we have used an adjustment factor. A derivation of the adjustment factor is included at the end of this document.

Everything presented here is preliminary and subject to correction, revision, and improvement. The following points should be taken into consideration when interpreting the results:

1. An oblique tow method was used during Phase 2 in 2017, 2018, and 2019. A surface tow method has now been used for Phase 2 since 2020.

2. Delta Smelt captured outside of the live box or cod end of the net could not be assigned to a specific tow and were excluded from this analysis. These fish are included in the daily catch summary and are indicated by a Gear Condition Code of 9. Delta Smelt captured in highly impaired samples, e.g., samples with large net blockages of debris or vegetation, were also excluded from this analysis. These fish are included in the daily catch summary and are indicated by a Gear Condition Code of 3.

3. The **Week** designations used here were defined out of convenience and are subject to change.

4. Current sampling is limited to areas of the Bay-Delta that can be safely navigated by the boats, which means areas with a minimum depth of approximately 8 feet. The abundance estimation method used here assumes that the density of fish in unsampled areas (i.e., those with depth less than 8 feet) is the same as in sampled areas (i.e., those with depth greater than or equal to 8 feet).

5. The methods of analysis used here remain in development.

Change Log

Report date May 7, 2021:

- On April 27, 20201, EDSM caught 2 Delta Smelt in the Sac DW Ship Channel stratum. Their fork lengths were 25.5 and 56 mm. According to an age-length key developed by the California Department of Fish and Wildlife, the smaller fish is *age-0*, meaning it was born in the same calendar year in which it was caught, while the larger individual is *age-1*, meaning it was born in a year prior to the year in which it was caught (see Appendix A of Mitchell et al. [2019] for the age-length key). During Phase 2, this implies that the smaller fish is in the postlarval/juvenile life stage while the larger individual is in the adult life stage.

  As a result, this report has been updated to show separate abundance estimates for postlarval/juvenile and adult life stages each week. We assume adults are uniformly distributed between 0.5- and 4.5-m depth and we account for the overlap of the 20mm net with this depth stratum during sampling. This is similar to the approach used by Polansky et al. [2019] for adult Delta Smelt caught in the Spring Kodiak Trawl Survey. Habitat volume estimates used to calculate abundance estimates are shown in Table 2 for the postlarval/juvenile life stage and Table 3 for the adult life stage.

Report date June 10, 2021:

- Corrections were made to data collected the week of May 24-27 as a result of on-going QA/QC. Sampling the week of June 1 was limited due to boat issues.

Results

Table 1: Delta Smelt catch summary and abundance estimates by week, stratum, and life stage. Age-0 refers to the postlarval/juvenile life stage and age-1 refers to the adult life stage. An asterisk (*) is used to emphasize weeks when no Delta Smelt were caught and a dash (-) is used to indicate that sampling did not occur or that a quantity could not be calculated. In order to avoid confusion, weekly totals are only calculated when sampling has occurred in every stratum. Sample volumes are in cubic meters.

| Stratum	Number of Sites	Number of Tows	Number Caught Age-0	Number Caught Age-1	Total Sample Volume	Abundance Estimate (95% CI) Age-0	Abundance Estimate (95% CI) Age-1
Week 1: March 29 - April 1, 2021							
Suisun Bay	5	10	0	0	9,267	0*	0*
Suisun Marsh	10	20	0	0	18,389	0*	0*
Lower Sacramento	5	10	0	0	9,818	0*	0*
Cache Slough LI	5	10	0	0	8,838	0*	0*
Sac DW Ship Channel	10	20	0	0	19,122	0*	0*
Lower San Joaquin	5	10	0	0	9,510	0*	0*
Total	40	80	0	0	74,944	0*	0*
Week 2: April 12 - 16, 2021							
Suisun Bay	10	20	0	0	18,654	0*	0*
Suisun Marsh	5	10	0	0	9,208	0*	0*
Lower Sacramento	5	10	0	0	9,630	0*	0*
Cache Slough LI	5	10	0	0	9,483	0*	0*
Sac DW Ship Channel	10	20	2	0	19,157	49,733 (7,109; 177,405)	0*
Lower San Joaquin	5	10	0	0	9,019	0*	0*
Total	40	80	2	0	75,151	49,733 (7,109; 177,405)	0*
Week 3: April 19 - 23, 2021							
Suisun Bay	5	10	0	0	9,188	0*	0*
Suisun Marsh	5	10	0	0	9,368	0*	0*
Lower Sacramento	5	10	0	0	9,905	0*	0*
Cache Slough LI	5	10	0	0	9,548	0*	0*
Sac DW Ship Channel	10	20	0	0	20,226	0*	0*
Lower San Joaquin	10	20	0	0	18,703	0*	0*
Total	40	80	0	0	76,937	0*	0*
Week 4: April 26 - 29, 2021							
Suisun Bay	5	10	0	0	9,778	0*	0*
Suisun Marsh	5	10	0	0	9,421	0*	0*
Lower Sacramento	5	10	0	0	9,034	0*	0*
Cache Slough LI	10	20	0	0	18,577	0*	0*
Sac DW Ship Channel	10	20	1	1	19,653	1,739 (240; 6,291)	2,685 (371; 9,711)
Lower San Joaquin	5	10	0	0	9,735	0*	0*
Total	40	80	1	1	76,199	1,739 (240; 6,291)	2,685 (371; 9,711)
Week 5: May 3 - 7, 2021							
Suisun Bay	5	10	0	0	9,603	0*	0*
Suisun Marsh	10	20	0	0	18,907	0*	0*
Lower Sacramento	5	10	1	0	9,970	9,143 (1,268; 33,023)	0*
Cache Slough LI	5	10	0	0	9,877	0*	0*
Sac DW Ship Channel	10	20	3	0	19,353	5,299 (734; 19,149)	0*

Table 1: Delta Smelt catch summary and abundance estimates by week, stratum, and life stage. Age-0 refers to the postlarval/juvenile life stage and age-1 refers to the adult life stage. An asterisk (*) is used to emphasize weeks when no Delta Smelt were caught and a dash (-) is used to indicate that sampling did not occur or that a quantity could not be calculated. In order to avoid confusion, weekly totals are only calculated when sampling has occurred in every stratum. Sample volumes are in cubic meters.

Stratum	Number of Sites	Number of Tows	Number Caught Age-0	Age-1	Total Sample Volume	Abundance Estimate (95% CI) Age-0	Age-1
Lower San Joaquin	5	10	0	0	9,460	0*	0*
Total	40	80	4	0	77,170	14,442 (3,235; 42,027)	0*
Week 6: May 10 - 13, 2021							
Suisun Bay	5	10	0	0	9,624	0*	0*
Suisun Marsh	5	10	0	0	10,009	0*	0*
Lower Sacramento	5	10	0	0	10,515	0*	0*
Cache Slough LI	5	10	0	0	9,914	0*	0*
Sac DW Ship Channel	9	18	0	0	17,590	0*	0*
Lower San Joaquin	5	10	0	0	9,418	0*	0*
Total	34	68	0	0	67,069	0*	0*
Week 7: May 17 - 21, 2021							
Suisun Bay	8	16	0	0	16,122	0*	0*
Suisun Marsh	5	10	0	0	10,177	0*	0*
Lower Sacramento	3	6	0	0	6,166	0*	0*
Cache Slough LI	3	6	0	0	6,238	0*	0*
Sac DW Ship Channel	3	6	0	0	5,707	0*	0*
Lower San Joaquin	4	7	0	0	6,096	0*	0*
Total	26	51	0	0	50,506	0*	0*
Week 8: May 24 - 27, 2021							
Suisun Bay	5	10	0	0	10,992	0*	0*
Suisun Marsh	5	10	0	0	11,062	0*	0*
Lower Sacramento	4	8	0	0	7,975	0*	0*
Cache Slough LI	5	10	0	0	10,165	0*	0*
Sac DW Ship Channel	10	20	0	0	20,311	0*	0*
Lower San Joaquin	10	20	0	0	20,180	0*	0*
Total	39	78	0	0	80,685	0*	0*
Week 9: June 1 - 4, 2021							
Suisun Bay	5	10	0	0	10,359	0*	0*
Suisun Marsh	0	-	-	-	-	-	-
Lower Sacramento	0	-	-	-	-	-	-
Cache Slough LI	0	-	-	-	-	-	-
Sac DW Ship Channel	0	-	-	-	-	-	-
Lower San Joaquin	3	6	0	0	6,041	0*	0*
Total	8	16	0	0	16,400	-	-
Week 10: June 10 - 11, 2021							
Suisun Bay	0	-	-	-	-	-	-
Suisun Marsh	0	-	-	-	-	-	-
Lower Sacramento	5	10	0	0	9,504	0*	0*
Cache Slough LI	0	-	-	-	-	-	-

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Stratum	Number of Sites	Number of Tows	Number Caught Age-0	Number Caught Age-1	Total Sample Volume	Abundance Estimate (95% CI) Age-0	Abundance Estimate (95% CI) Age-1
Sac DW Ship Channel	5	10	0	0	9,711	0*	0*
Lower San Joaquin	0	-	-	-	-	-	-
Total	10	20	0	0	19,216	-	-
Week 11: June 14 - 17, 2021							
Suisun Bay	5	10	0	0	9,693	0*	0*
Suisun Marsh	5	10	0	0	9,584	0*	0*
Lower Sacramento	10	20	0	0	19,714	0*	0*
Cache Slough LI	5	10	0	0	9,801	0*	0*
Sac DW Ship Channel	10	20	0	0	18,664	0*	0*
Lower San Joaquin	5	10	0	0	9,714	0*	0*
Total	40	80	0	0	77,171	0*	0*
Week 12: June 21 - 25, 2021							
Suisun Bay	7	14	0	0	15,455	0*	0*
Suisun Marsh	5	10	0	0	10,567	0*	0*
Lower Sacramento	5	10	0	0	9,516	0*	0*
Cache Slough LI	5	10	0	0	9,596	0*	0*
Sac DW Ship Channel	5	10	0	0	9,456	0*	0*
Lower San Joaquin	5	10	0	0	10,900	0*	0*
Total	32	64	0	0	65,491	0*	0*

Delta Smelt Abundance Estimates Over Time
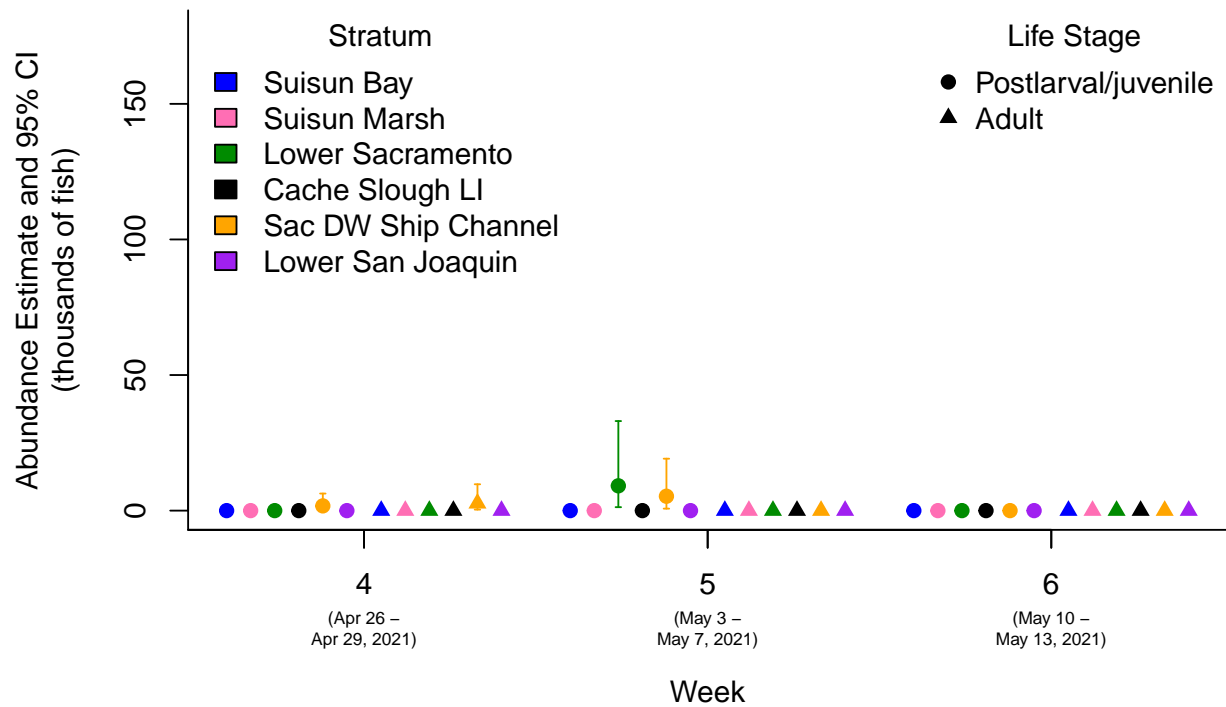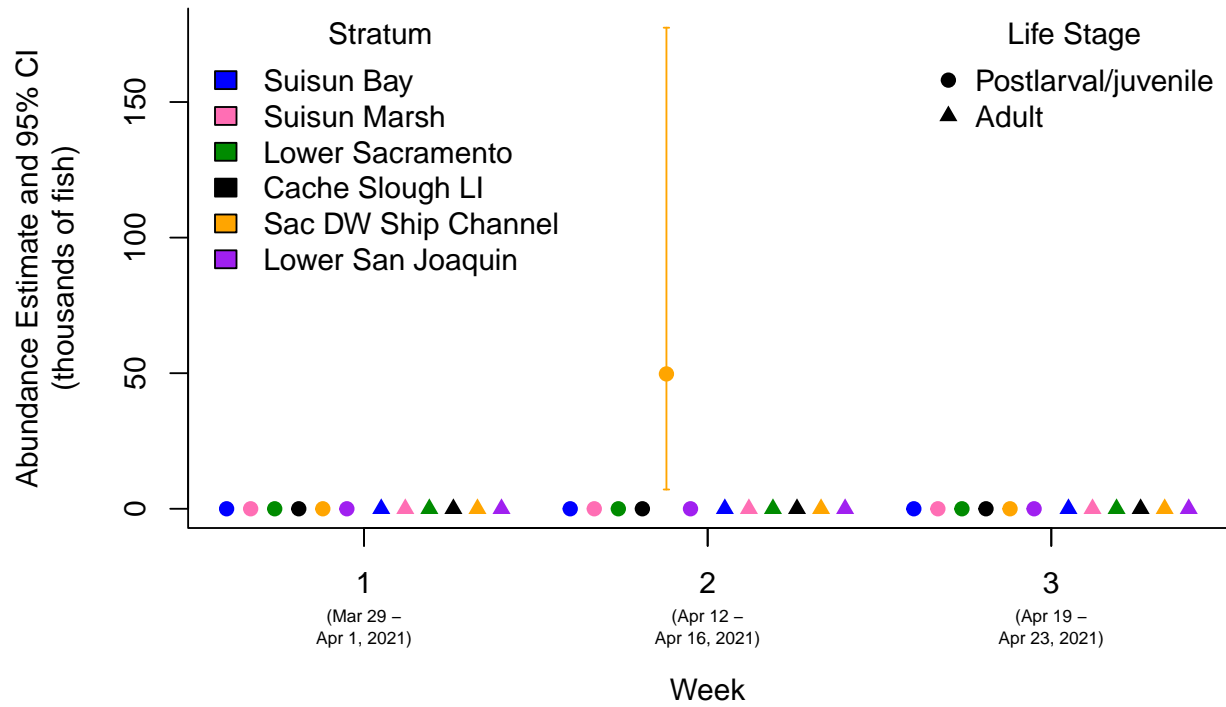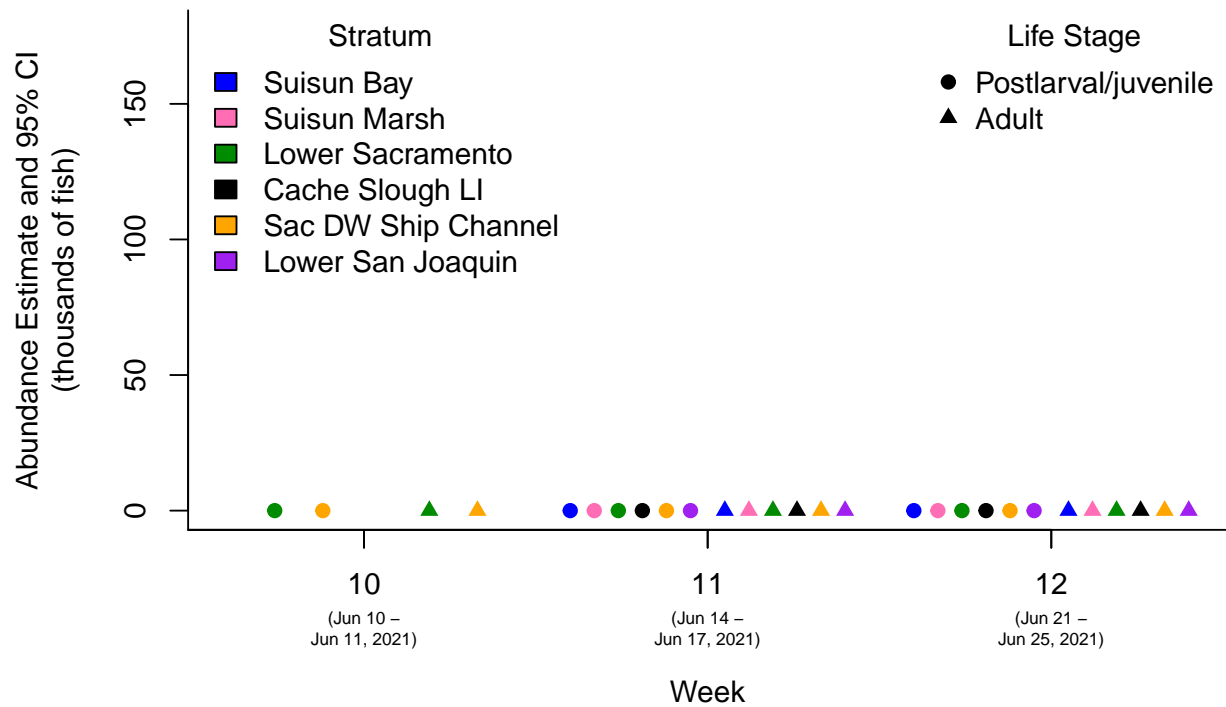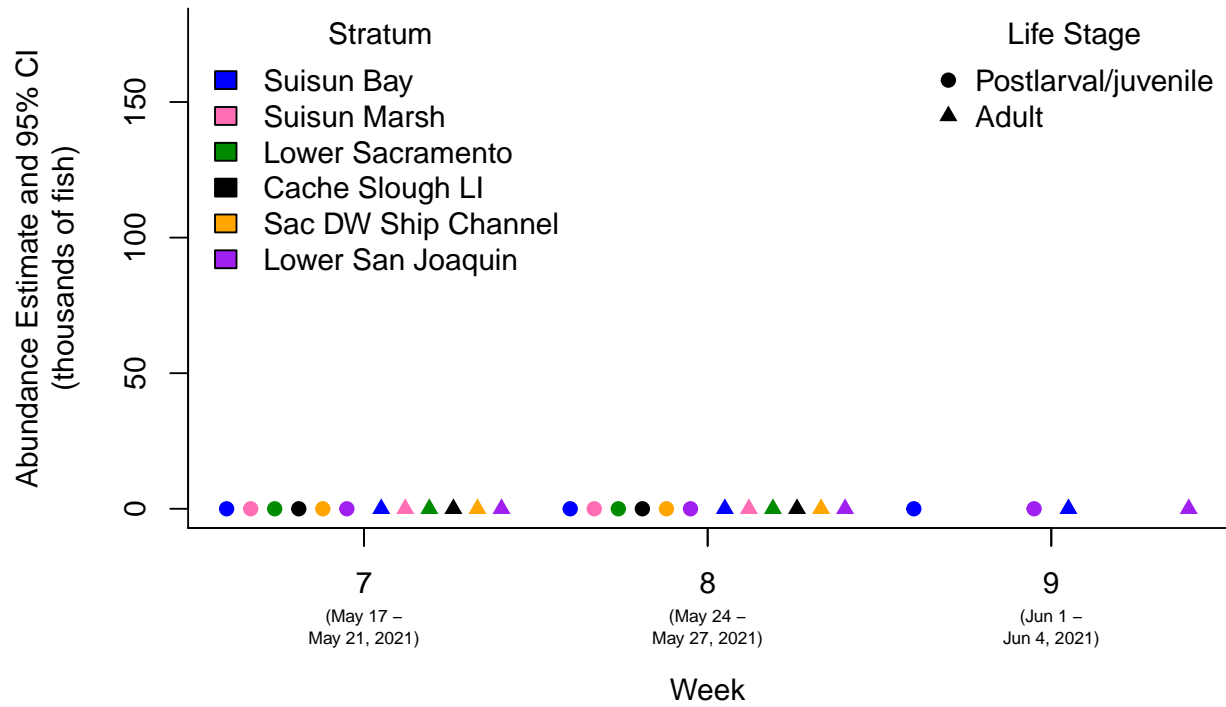
Week 1 (March 29 – April 1, 2021)

Delta Smelt Total Catch by Site
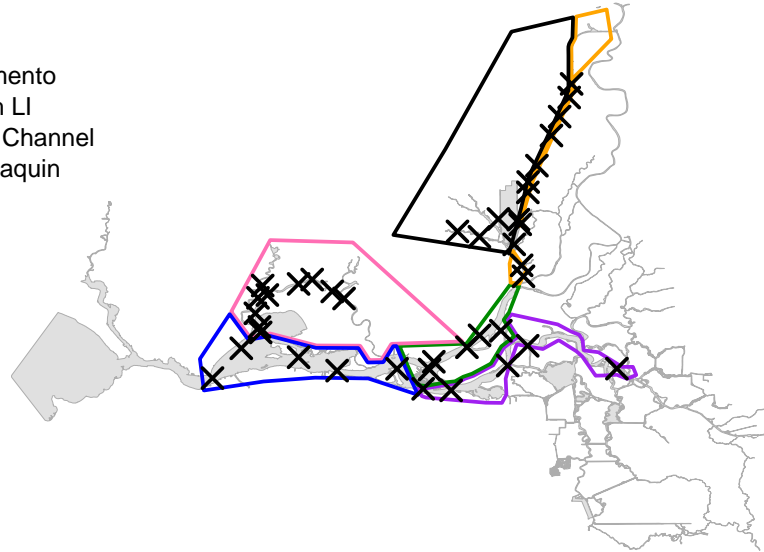
Week 2 (April 12 – 16, 2021)

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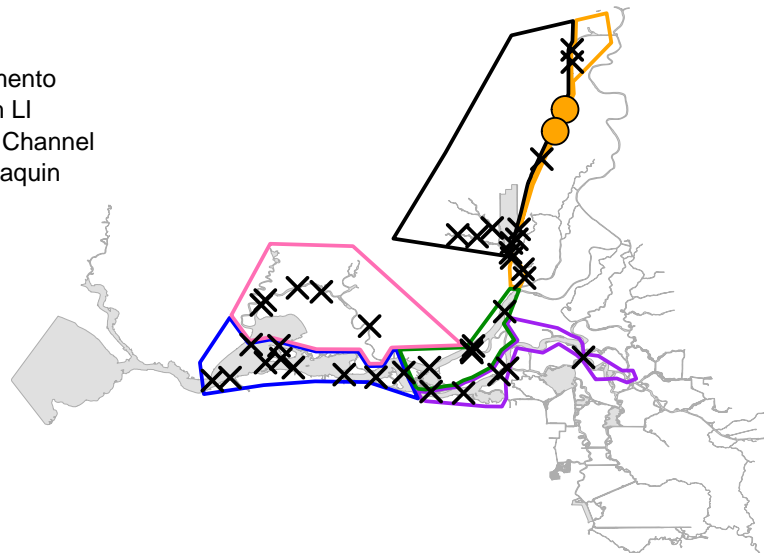
Week 3 (April 19 – 23, 2021)

Delta Smelt Total Catch by Site
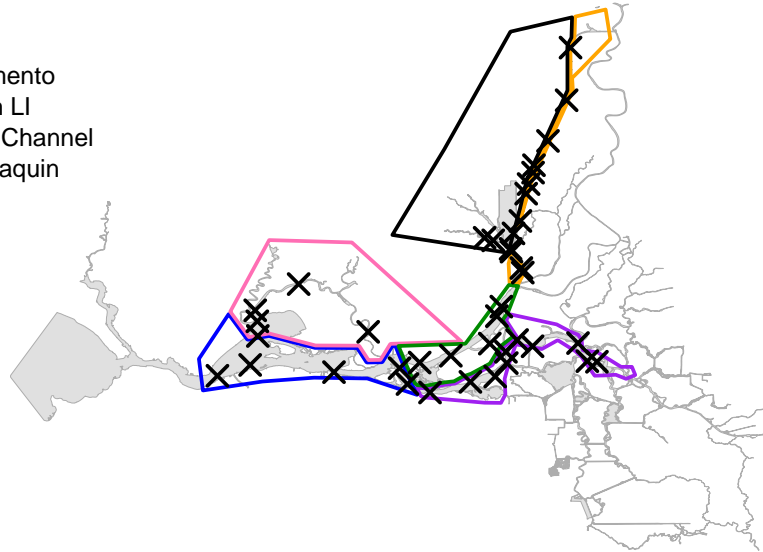
Week 4 (April 26 – 29, 2021)

Delta Smelt Total Catch by Site
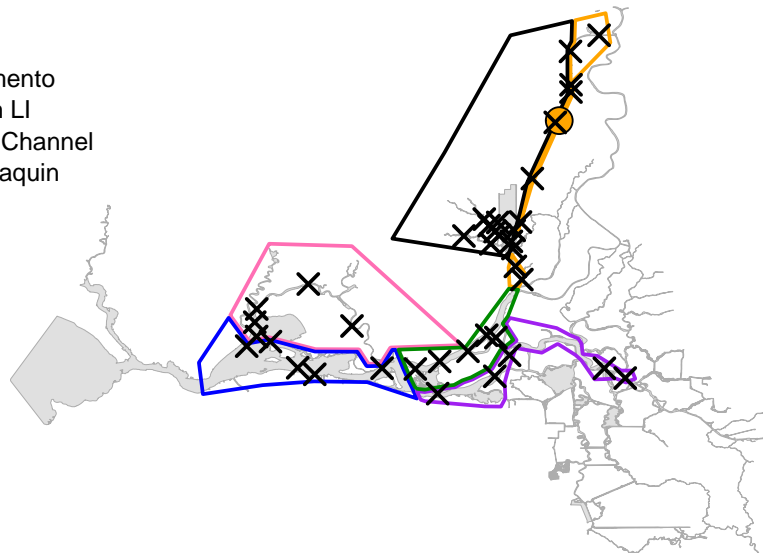
Week 5 (May 3 – 7, 2021)

Delta Smelt Total Catch by Site
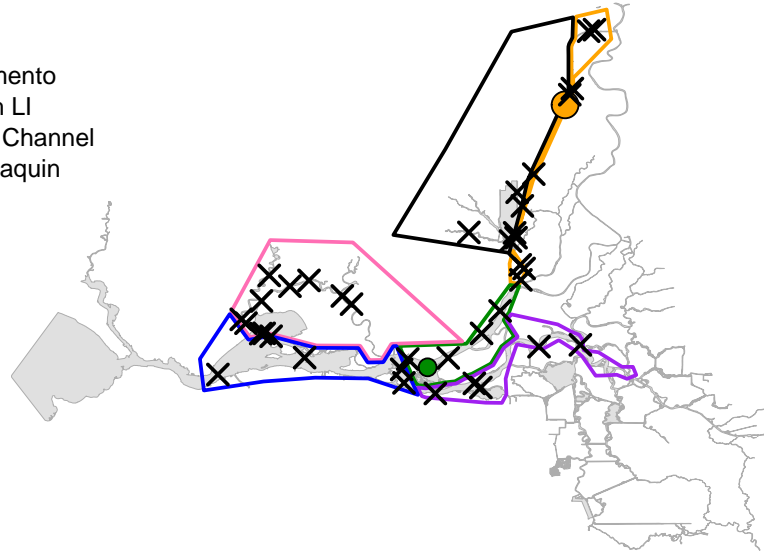
Week 6 (May 10 – 13, 2021)

Delta Smelt Total Catch by Site
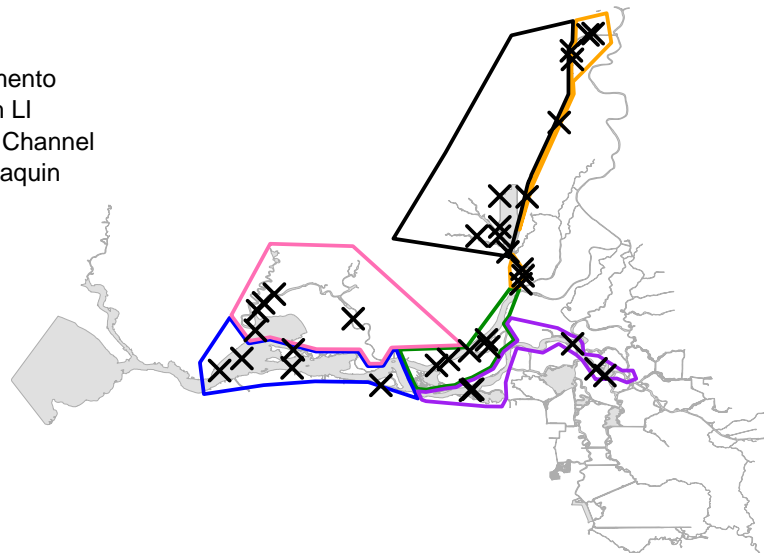
Week 7 (May 17 – 21, 2021)

Delta Smelt Total Catch by Site
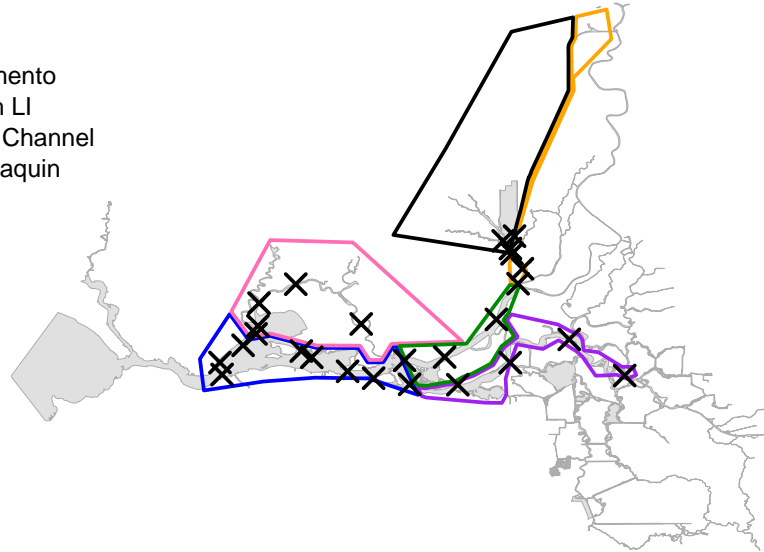
Week 8 (May 24 – 27, 2021)

Delta Smelt Total Catch by Site
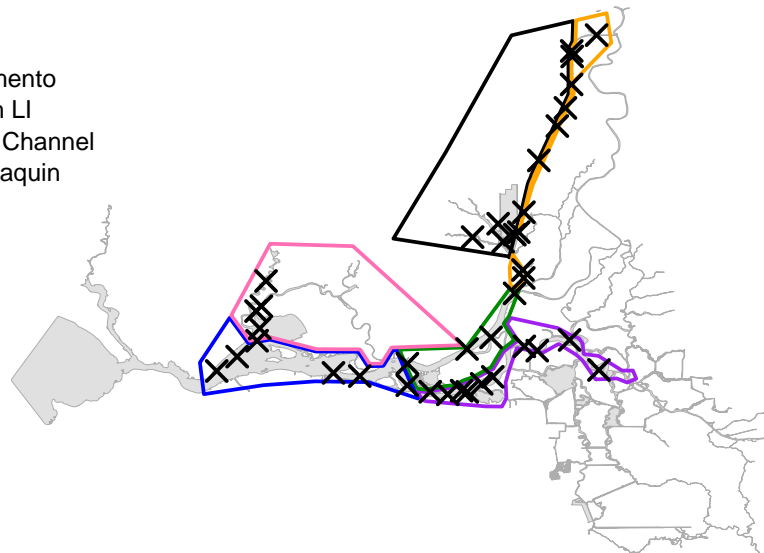
Week 9 (June 1 – 4, 2021)

Delta Smelt Total Catch by Site
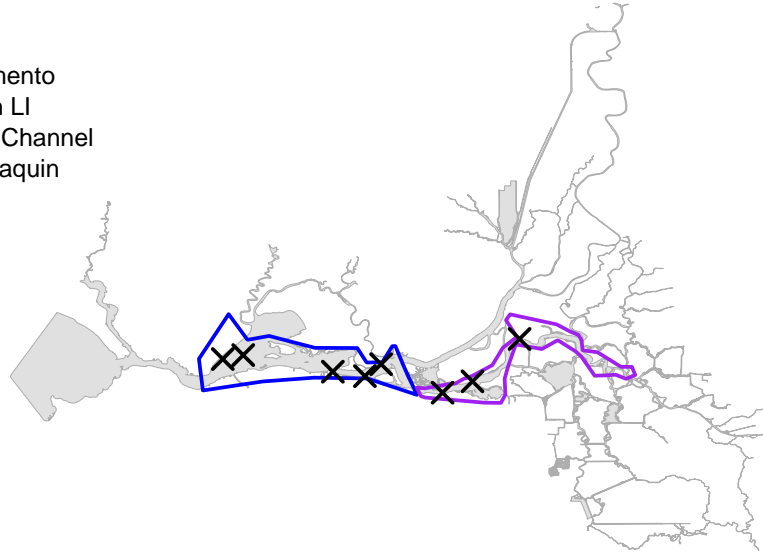
Week 10 (June 10 – 11, 2021)

Delta Smelt Total Catch by Site

Week 11 (June 14 – 17, 2021)

Delta Smelt Total Catch by Site

Total Catch

■ Suisun Bay
■ Suisun Marsh
■ Lower Sacramento
■ Cache Slough LI
■ Sac DW Ship Channel
■ Lower San Joaquin

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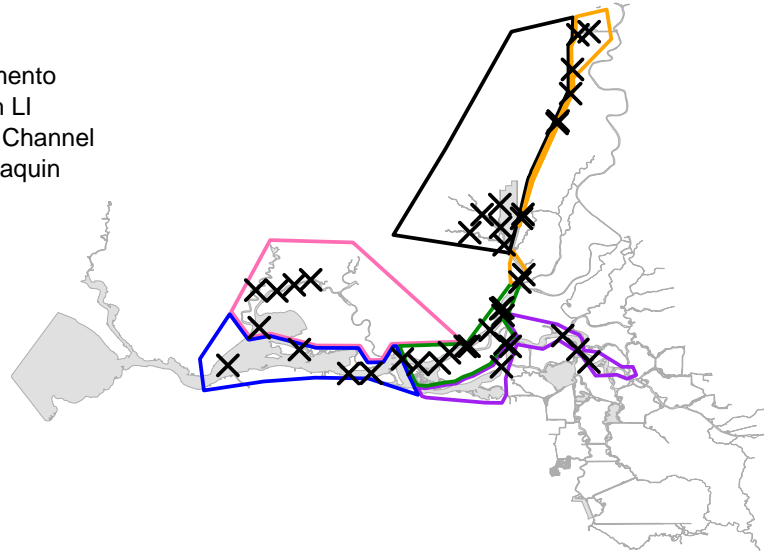
Week 12 (June 21 – 25, 2021)

Delta Smelt Total Catch by Site

Total Catch

■ Suisun Bay
■ Suisun Marsh
■ Lower Sacramento
■ Cache Slough LI
■ Sac DW Ship Channel
■ Lower San Joaquin
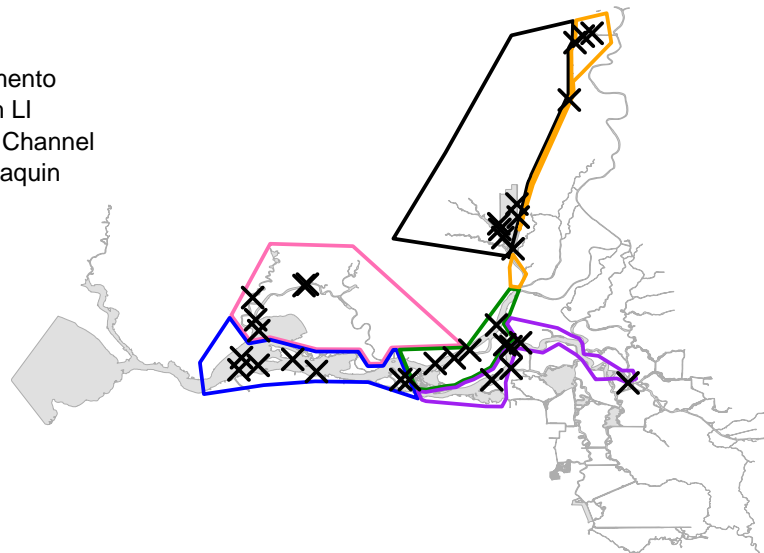
✕ 0

All Sampling Locations To Date
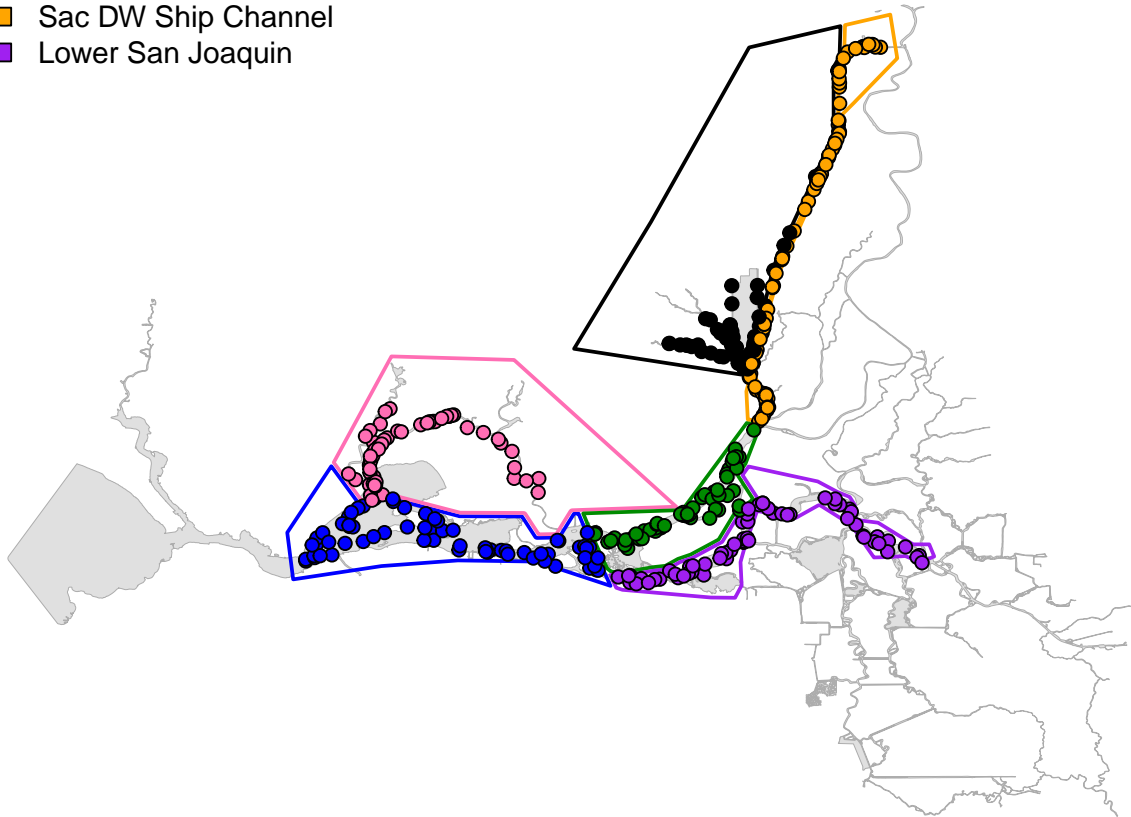
Habitat Volume Estimates

Table 2: Estimates of water volume (cubic meters) between 0 and 10-m depth, by stratum.

Stratum	Volume
Cache Slough LI	52,180,503
Lower Sacramento	171,562,419
Lower San Joaquin	232,126,861
Sac DW Ship Channel	64,336,104
Suisun Bay	531,809,657
Suisun Marsh	106,744,669

Table 3: Estimates of water volume (cubic meters) between 0.5-m and 4.5-m depth, by stratum.

Stratum	Volume
Cache Slough LI	33,420,492
Lower Sacramento	88,162,170
Lower San Joaquin	122,096,565
Sac DW Ship Channel	30,411,491
Suisun Bay	285,840,678
Suisun Marsh	76,278,718

References

L. Mitchell, K. Newman, and R. Baxter. Estimating the size selectivity of fishing trawls for a short-lived fish species. *San Francisco Estuary and Watershed Science*, 17(1), 2019. URL http://dx.doi.org/10.15447/sfews.2019v17iss1art5.

L. Polansky, L. Mitchell, and K. B. Newman. Using multistage design-based methods to construct abundance indices and uncertainty measures for Delta Smelt. *Transactions of the American Fisheries Society*, 148 (4):710–724, 2019. URL https://doi.org/10.1002/tafs.10166.

D. L. Stevens and A. R. Olsen. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association*, 99(465):262 – 278, 2004. URL https://doi.org/10.1198/016214504000000250.

Appendix

Derivation of a density gradient adjustment factor to standardize Delta Smelt density estimates based on 20 mm surface tows:

During experimental larval sampling by EDSM staff in spring 2018 and spring 2019, surface tows with a 20 mm trawl generally produced higher catch-per-unit-effort (CPUE) of Delta Smelt than oblique or midwater tows. These differences in CPUE are likely caused by fish densities being higher at the surface than at depth, though other alternative or complementary explanations are possible. For example, it may be easier for post-larval and juvenile Delta Smelt to passively or actively evade the net during midwater and oblique tows than during surface tows.

Starting in 2020, Phase 2 switched from using oblique tows to using surface tows in an effort to increase its overall ability to detect early life stage Delta Smelt. Here we assume that (1) post-larval and juvenile Delta Smelt caught from April through June are located between the surface and 10 m depth, and (2) the density of post-larval and juvenile Delta Smelt has a positive value α at the water surface and decreases linearly to 0 at 10 m depth (Figure 1). The first assumption has been used previously in EDSM Phase 2 reports from 2017–2019 and by Polansky et al. (2019), all of which used data collected with oblique tows. The second assumption has not been explicitly used before, but does not affect density estimates based on oblique tows, as explained below.
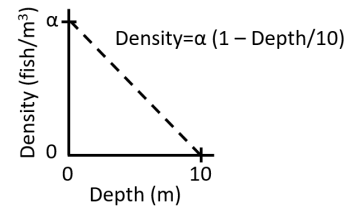

Figure 1. Fish density as a function of depth in the water column.

The true average density in the vertical stratum between 0 and 10 m can be calculated as:

$$\bar{\delta}_{true} = \frac{1}{10} \int_0^{10} \alpha \left(1 - \frac{x}{10}\right) dx = \frac{\alpha}{2}. \tag{1}$$

Using the 20 mm trawl's maximum net mouth height of 1.18 m and assuming, for simplicity, that the net mouth is rectangular (it is actually D-shaped), the average density as calculated from surface tows that sample the top 1.18 m of the water column is:

$$\bar{\delta}_{surface\ tow} = \frac{1}{1.18} \int_0^{1.18} \alpha \left(1 - \frac{x}{10}\right) dx = 0.941 \times \alpha = \frac{\alpha}{2} \times 1.882 = \bar{\delta}_{true} \times 1.882. \tag{2}$$

Then the true average density can be calculated from the surface tow average density as:

$$\bar{\delta}_{true} = \frac{1}{1.882} \times \bar{\delta}_{surface\ tow} = 0.5313 \times \bar{\delta}_{surface\ tow}, \tag{3}$$

and the density gradient adjustment factor is therefore 1/1.882 or approximately 0.5313. The density gradient adjustment factor is a function of the deeper stratum boundary, which in this case is 10 m. Because the San Francisco Estuary has variable water depths, this adjustment factor changes depending on sample location and environmental conditions that affect water depth. For simplicity, however, we have applied the single value 1/1.882 throughout the analysis. Note that no adjustment factor is needed for oblique tows because oblique tows sample from roughly the entire vertical cross-section of the stratum containing fish, in which case the integrals in Equations (1) and (2) are identical and the adjustment factor becomes one.

References
Polansky, L., Mitchell, L. and Newman, K.B. 2019. Using multistage design-based methods to construct abundance indices and uncertainty measures for Delta Smelt. Transactions of the American Fisheries Society, 148:710–724. Available at: https://doi.org/10.1002/tafs.10166